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A Dashboard Approach to Exploring & Assessing the Ground Operations Costs of Future Launch Vehicles

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1. Abstract

This paper summarizes a relatively simple executive dashboard approach to exploring and better understanding ground operations costs. These are the kind of costs incurred at the Kennedy Space Center (KSC), when receiving, processing, preparing, assembling, servicing and launching a vehicle to space. The purpose of the dashboard is to stir and assist communication about recurring ground operations costs by organizing costs in categories and describing these using rather simple terms. The descriptions should be understandable to anyone in government or the private sector. The data baseline may be Shuttle, but the dashboard is meant to stir significant questions about the cost structures of other systems such as the Space-X Falcon 9, the United Launch Alliance Atlas and Delta IV expenses which yield a service or price, or any proposed new heavy lift rocket. The new NASA FY 11 budget direction has emphasized "***significantly lower operations costs than current systems***". Assisting communication in the consideration of investments that must address this emphasis should prove invaluable. The dashboard is shown in **Figure 1**.

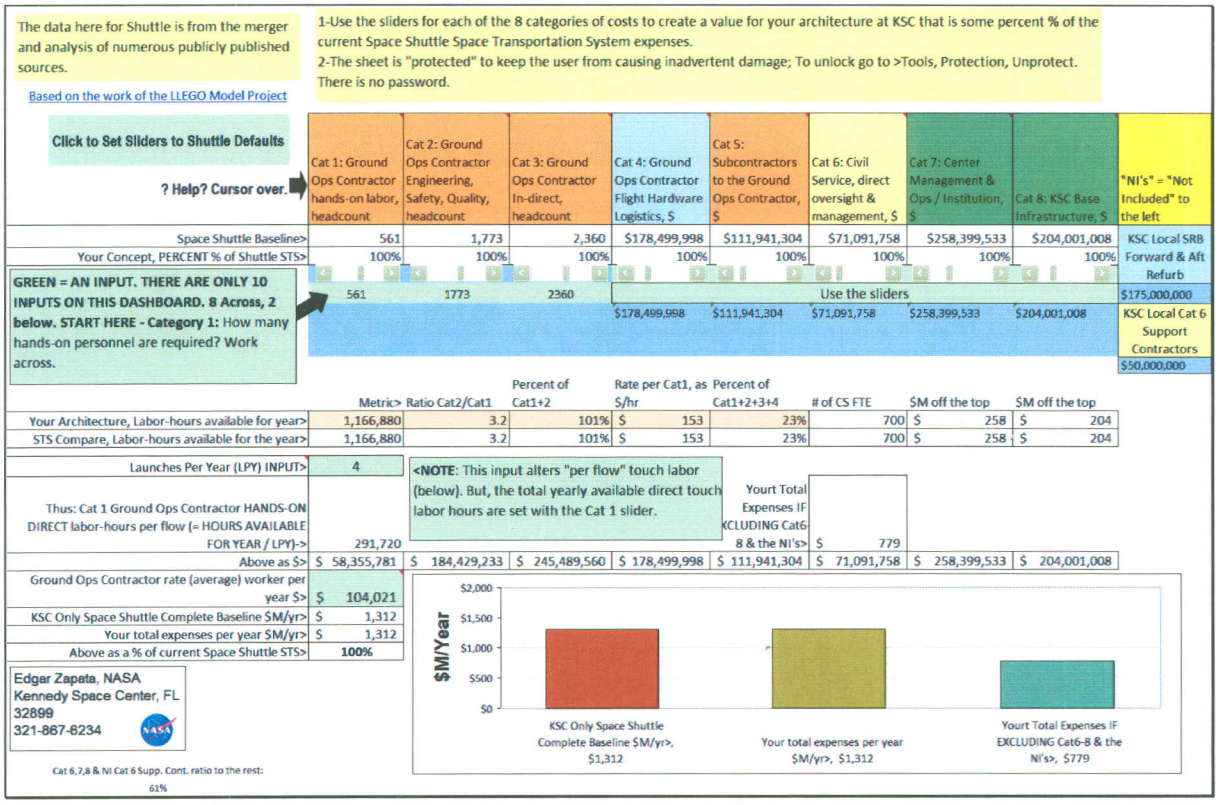

Figure 1: The entire executive dashboard, shown with the default Shuttle setting.
Version as of 05-20-10.

2. Background

It's too often in the nature of cost estimates for future launch vehicles to be complex and inaccessible. Details in a cost estimate should be provided to add insight and confidence to the decision makers and the decision making and budgeting process. Unfortunately, abundant detail often underlies a cost estimate for the purpose of obscuring, appearing intimidating and credible to managers, but lacking underlying substance. A big picture perspective alongside the estimate, important to its credibility, is also discarded on the path of overly complex math[1] for assorted reasons. Cost models and their associated program [2]risk management processes can easily become complex means by which actions and risks are moved around in a shell game never to land all at once into a cohesive picture.

Inversely, inappropriate simplification often occurs once trying to sell a program to sponsors, congressional, presidential or otherwise. The complex estimate is enlisted into a use when needed, but first transformed into notions and generalizations mixed in with plans and beliefs that are wholly divorced from the estimate as well as from eventual plans and actions. This results in a loss of credibility to all, the estimators, the program managers, the institution, and the name of the agency itself.

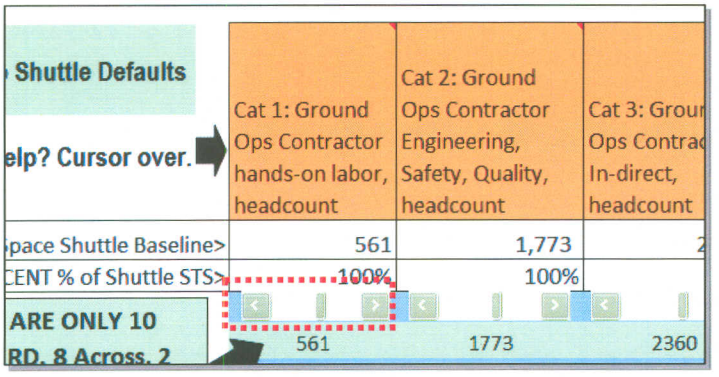

Figure 2: Sliders used to set inputs in the process of exploring costs.

Presented here, while trying to avoid too much math, or too much simplification, is a "lets explore" approach to cost estimating for the ground operations portion of a future launch vehicle at the Kennedy Space Center (KSC). To address future cost estimates in the field of ground operations for launch vehicles at KSC, and to encourage critical thinking, a dashboard for costs and a structure by which to think about costs has been created. These "costs" referred to are primarily contractor costs under a structure where a federal agency, NASA, buys the launch vehicle and/or the service to prepare and launch the vehicle. This means civil servants then, who will manage the purchase of this effort to be performed by the contractor workforce. By necessity, handing over large amounts of taxpayer funds entails, according to the purchasing, sourcing or "procurement" model, government employees overseeing, getting insight into, or assuring that the contractor chosen performs according to the contract with the pricing terms specified. All of this effort that is associated with a vehicle, be it contractor or civil servant, requires some infrastructure. In the case of a private corporation, immediate thoughts about infrastructure may bring to mind different modes of transportation (road, rail, air, waterways, etc) or utilities (electricity, water, waste management, etc) and so on. These concepts of the "supplier/contractor", the "customer/buyer" and the "place/infrastructure" will repeat often in this brief exploration of costs. The goal of this exploration is to see how past experience can help guide the improvements that will one day make access to space more affordable, reliable (and safer) and in general more routine.

Note: This brief paper does not address other factors in the current economic (or some might say non-economic) paradigm of launch vehicles, such as in-direct subsidies, infrastructure subsidies, R&D subsidies, or policy factors in costs (e.g., ITAR and related regulation), non-proliferation policy factors in costs, and many related factors.

3. Caveats

- This dashboard is for KSC costs only.
- These KSC costs may be managed contractually by KSC, Johnson Space Center (JSC) or Marshall Space Flight Center (MSFC), but they are all local cash flows into the KSC area.
- There are only 10 variables in the dashboard; most of the value of the dashboard is in considering and exploring aspects of these 10 variables further, hand in hand with any estimation work outside of the dashboard.
- This is a work in progress. The model will evolve out of synch and ahead of this document. Feedback is encouraged.

4. The Dashboard and Critical Questions

Shown in **Figure 3** are the dashboard cost categories created to explore KSC ground operations costs. There is a limited intent here, mostly having to do with forcing some critical questions –

- Did you think of this to include it?
- If your not covering it, who is?
- What drives the costs value, the real cause?
- How do your cost categories compare to each other? (e.g., the ratio of Category 3 to the rest? etc).

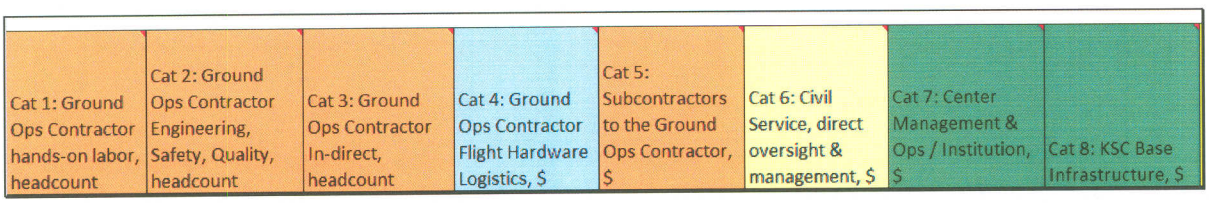

Figure 3: The dashboard cost categories. Consider these like departments in a company, or job functions, arranged by similarity.

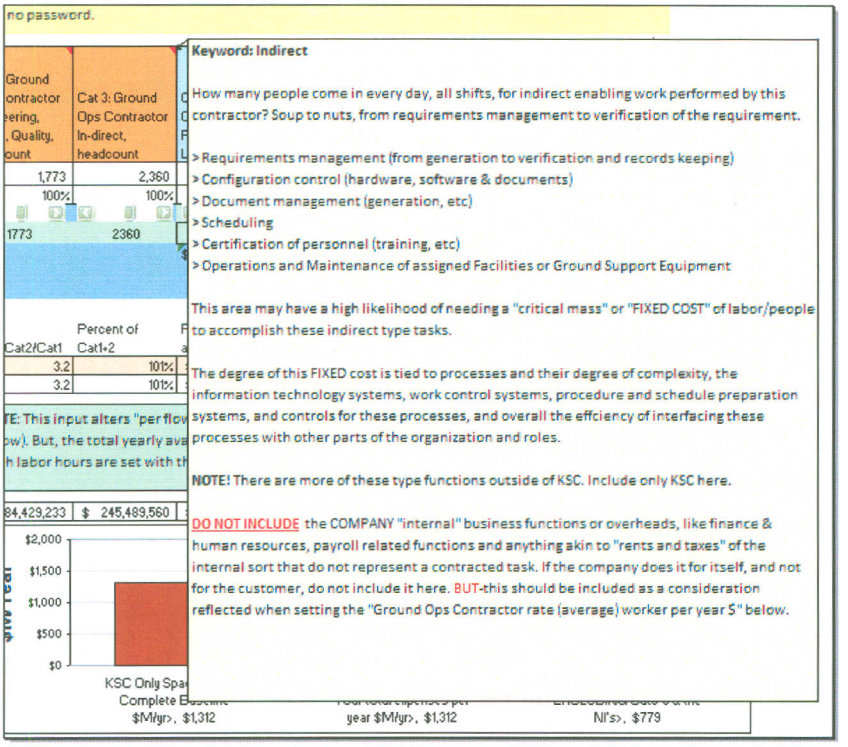

Figure 4: Cursor-over feature explains Category 3 Contracted Indirect costs to consider in your exploration of costs for a future concept.

Each category has a cursor-over feature that explains what to consider in the category. An example is shown in **Figure 4**. In this example the category explained is what might be called "contractor indirect" by some (the way the term is used here), "overhead" by others, "enabling", "business processes", "business systems", and so on according to the user. If you are a buyer of a part, and this is an expense to your supplier, you may have no insight into this at all except to see it reflected in your cost as the price. Alternately, if you see this as something you purchase along with the hardware and you wish to assure that the process is actually being performed as was expected in the contract, then you'll likely want to see what this is all about in sufficient detail to see its cost to you. Inversely, if you are the supplier you'll see this as something to improve, either by reducing its cost or keeping the cost the same as productivity increases, amortizing its expenses over more and more units sold. Each Category in the dashboard has such an explanation to stir the critical questions posed previously.

As an additional caveat, it's not possible to be 100% complete in the space given for a short explanation of a cost category, especially if wishing to keep it short. Further research and questioning will always be required – does that category of cost do this too? Is that in this category of costs?

5. Using the Dashboard

An example system is being explored below. Here the user has set some values by putting on a hat that wants to tally all the costs of a relatively simple expendable launch system, minus the manufacturing of the hardware. The user is tallying only their costs, from the point of view of the manufacturer who knows that costs will be incurred from the point this is delivered to the launch site and through launch.

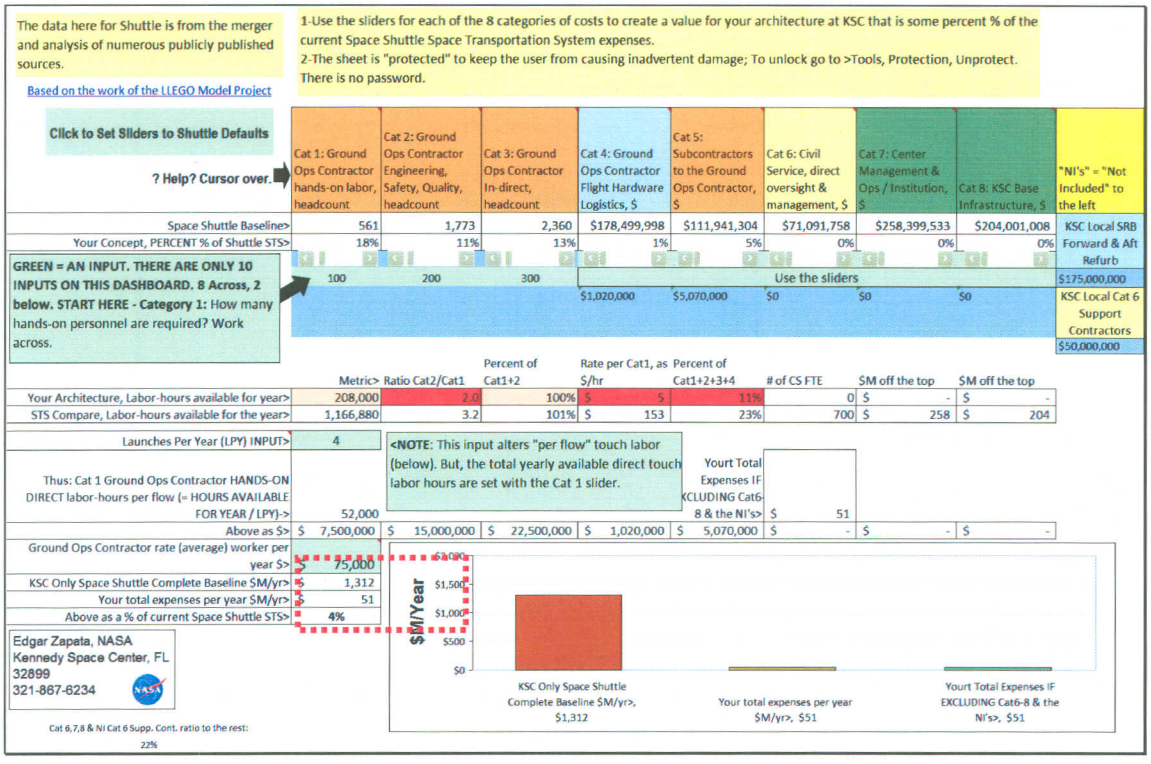

Figure 5: A sample case where total yearly "ops" or "launch site" costs are $51M. This excludes manufacturing as well as any on-orbit operations for the payload.

How many people will provide touch labor at the site to assemble, prepare, service and launch the rocket (Category 1)? How many engineers will work with the technicians (Category 2)? Who will manage and control drawings, configuration information and documents (Category 3)? Who will order a part should a problem arise, or have some parts on hand already (Category 4)? Will I need some outside company to provide me a service I don't have in-house (Category 5)? What of my place of operation (Category 8)? If this is a government purchase, how do I assure contracting has proper management of taxpayer funds (Category 6, 7)?

Supposing that these costs represent some percent of total costs, once manufacturing is added in, a total cost per launch for these 4 launches can be derived (left to the reader).

6. Critical Analysis, Sanity Checks and Causality

The really important questions about the cost categories have to do with causes and results. What causes a cost? What product comes from the cost? Numerous sub-topics would follow these lines of thought –

- Supply Chain Management (SCM): In this science the flow of information and materials from the birth of a requirement to its fulfillment is seen as a series of processes. The process perspective is related to a product and a customer. The practice of SCM leads inevitably to re-engineering those processes (you can't reengineer a process until you understand it), then to applying information technology where ever appropriate (from servers or clouds of computing all the way to useful information that causes something productive to happen, this area especially assists through metrics in seeing where to focus limited resources), and to practices that make the dividing line between suppliers and customers less of a barrier and more of an asset in delivering product. A business's technology (speed and costs) for moving from an assortment of product innovations to a specific product line can be the difference between success and failure.
- Activity Based Costing: In this science a resource is identified and attached to an activity that generates a product. The activity may be "assigning funds", "awarding a contract" or "releasing a drawing". Resources are most often people. The resource that goes to each activity is understood enabling a relationship between the resource and the productivity. Productivity may be "122 contracts", "228 drawings" or "23 bench tests". This insight enables modifying the process to enable greater unit product flow for any given resource.

These are just a couple of examples of how to approach causal questions of cost. Most such practices will require data, which extends to product data management (PDM) systems and Product Lifecycle Management (PLM) systems. Beyond engineering or other related metadata there will always be a need that costs be part of such product databases. Cost data must be formatted and useful enough to support decisions that link cost and benefits for the improvements independent of the costs of current technology.

7. Future Work

It is possible to take this dashboard concept further in various directions:

1. Expand the Shuttle Categories to include manufacturing, for the External tank and the Solid Rocket Motor's as well as the Mission and Flight Control costs.

2. Add a switch where Shuttle variants have their related element costs with a feature that highlights or warns when the cost has dropped below the fixed yearly cost of that element. This data on [3]fixed costs is available. This would encourage thinking about what drives fixed costs so as to alter it or increase its productivity.

3. Translate this dashboard into a web version suitable for generating real time metrics, updated daily, with trending, metadata and links to further resources. The target users could be NASA and contractor executives, contracting personnel, cost estimators and program/project managers.

8. LLEGO

The dashboard has been integrated into a much more complex model called the [4]Launch & Landing Effects Ground Operations (LLEGO) model. Its use described in this paper is merely as a standalone tool with mostly a descriptive purpose meant to improve and stir communication.

About the Author

Mr. Zapata has worked with NASA at the Kennedy Space Center since 1988. In that time he has held responsibility for Shuttle systems including the Shuttle External Tank and the Shuttle cryogenic propellant loading systems, and related flight and ground propulsion systems. Starting in the mid 90's he began work to translate the operations experience into improvements in flight and ground system designs for achieving improvements in ground operations processing from landing through launch, in all aspects from direct to in-direct operations. He participated in the Explorations Systems Architecture Study or "ESAS" in 2005, contributing launch and landing ground operations cost estimates and integrating the KSC cost estimates into the ESAS life-cycle cost analysis.

Most recently Mr. Zapata has performed (1) strategic NASA agency level and Constellation future scenario analysis, (2) analysis supporting the Constellation Standing Review Board, by providing independent analysis of the KSC ground operations project, and (3) analysis and recommendations as part of the NASA Programmatic Risk Assessment team in support of the 2009 Presidentially Appointed Review of Human Space Flight Plans Committee.

Mr. Zapata looks forward to the day when access to space is safe, routine and affordable as a result of taking advantage of, quantifying and understanding the experience and lessons of past and current space transportation systems operations.

For related material: http://science.ksc.nasa.gov/shuttle/nexgen/rlvhp.htm

[1] Any math beyond addition and multiplication is avoided in this exploration of launch vehicle costs via a dashboard. Quantifying to the Nth degree is avoided on purpose. Consider the observation by Michael Lewis in his book "The Big Short" – "Did you ever hear the word 'derivatives'?" he said. "Do you think *our* guys [the lower third of a college class, who—Trillin argues—were the typical people who went to Wall Street a quarter of a century ago] could have invented, say, credit default swaps? Give me a break! They couldn't have done the math. When the smart guys started this business of securitizing things that didn't even exist in the first place, who was running the firms they worked for? Our guys! The lower third of the class! Guys who didn't have the foggiest notion of what a credit default swap was." Viewed online at http://www.tnr.com/book/review/the-worst-and-the-brightest on 5-20-10.

[2] The notion of risks being moved around, like canaries in a truck, is not unique to space program cost estimating and management. In the recent financial turmoil, insurance in the form of credit default swaps (CDS) draws an analogy to merely moving risks around and eventually encouraging underlying fundamentals to decline. From "Wall Street Reform That will Prevent the Next Financial Crisis" By U.S. Senator Edward E. Kaufman, March 11, 2010 –"In fact, one of the primary purposes behind the securitization market was to arbitrage bank capital standards. Banks that could show regulators that they could offload risks through asset securitizations or through guarantees on their assets in the form of derivatives called credit default swaps (CDS) received more favorable regulatory capital treatment, allowing them to build their balance sheets to more and more stratospheric levels." Viewed online at http://kaufman.senate.gov/press/floor_statements/statement/?id=aca5b91a-6e51-4d6b-a367-414ad9641500 on 5-20-10

[3] "A Review of the NASA Space Shuttle and Human Space Flight Fixed and Variable Space Transportation System Costs", Edgar Zapata, NASA KSC, Viewed online at: http://science.ksc.nasa.gov/shuttle/nexgen/Shuttle_FixVar.htm on 5-24-10.

[4] "LLEGO - Launch & Landing Effects Ground Operations cost model" Viewed online at: http://science.ksc.nasa.gov/shuttle/nexgen/LLEGO_main.htm on 5-24-10.